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SELECTIONS ON HYDROGEOLOGY AND ENGINEERING GEOLOGY

- COMMUNIST CHINA -

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SELECTIONS ON HYDROGEOLOGY AND ENGINEERING GEOLOGY

[The following are translations of selected articles from Shui-wen Ti-chih Kung-ch'eng Ti-chih, No. 11, Peiping, 12 November 1959]

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SOME OBSERVATIONS ON HYDROGEOLOGICAL PROSPECTING WORK OF PERMAFROST AREAS

/Following is the translation of an article by Cheng Ch'i-p'u (6774 0796 3184), the 3rd Design Institute of the Ministry of Railroads, in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 13-15./

As a consequence of the flying development of the forest industry since the liberation, the new railroads, the lumbering industry and the forestry chemical industry have been extending deeply toward Ta-hsiao Hsing-an-ling. During the past years, we made reconnaissance surveys along railroads, more than 1000 km., the result of which illustrates that there are different kinds of permafrost layers in the permafrost areas of Northeast China. The writer presents some points of understanding from railroad hydrogeological reconnaissance for your reference and comments. In case of disagreements or mistakes in the article, please advise and correct.

I. Hydrogeological characteristics and types of underground water of the permafrost areas.

According to our observations from working experiences, the depth between the ground surface and the upper permafrost layer, the thickness of the frost layer, and its distribution vary with the heat conductivity of the soil, terrain, topography, underground water activity, climate and other factors in the district.

In Chin-lin district, north latitude 51°, east longitude 122°, the temperature of different soils at the same depth are obtained as per the following table:

(See next page)

During the reconnaissance survey, it was commonly observed that the depth between the upper frost layer and the ground surface is only 0.3-0.5 m, some places reaching 3-5m, while the thickness of the frost layer varies at some

Observed Depth / Name of Layer	Different Depths			Ave. Temp. during Observ.	Date of Observations
	0.8 m	1.6 m	3.2 m		
Clayey Rocks	−9.2°C	−7.3°C	−4.8°C	− 33°C	Jan. 5, 1956 to Jan. 25, 1958
Sandstones or Sand-gravel	−8.2°C	−6.2°C	−3.9°C	− 32°C	
Clayey Rocks & Sandstones	−8.7°C	−6.8°C	−4.1°C	−32.5°C	

Note: The ground temperatures are average value during observational period.

places only 1-2 m and others up to 40-50 m. For instance, during surveying at the Yin-a railroad station, it was found that both sunny and shady sides are covered by clayey rocks with sandstones in between. After drilling, it revealed that the permafrost layer does not exist on the sunny side, but does exist on the shady side, 2 m in depth.

Under the different heat conductivity of soil, the general depths between the permafrost layer and the ground surface are listed below:

Clayey-syenite	Clayey rocks	Clayey rocks w/sand-gravel	Sandstones or sand-gravels
0.5-1.2 m.	1.5-2.2 m.	1.8-2.6 m.	2.5-3.5 m.

The underground buried water conditions in permafrost areas are quite different from one area to another. H. N. "To-erh-ch'i-szu-hsin-chiang" divided the underground water of permafrost areas into three catagories: upper frostwater, intermediate frost water and lower frost water. The permafrost areas in Northeast China have these three types of underground water extensively distributed, especially abundant is upper frost water. The inhabitants of Ta Hsing-an-ling call these three types of underground water floating water, mid-water and bottom water. Their general characteristics are as follows:

1. The upper water of the frost layer: This is an underground water that exists above the frost layer. Its activity changes as the atmospheric temperature changes. It starts freezing in mid-September, the underground water of liquid phase becoming solid phase. It melts in early April, the underground water of solid phase converting back to liquid phase. The thickness of the activity layer greatly varies with the periodic variation of the atmospheric temperature. This water's activity is a function of the climatic conditions, the topographical locations, soil heat conductivity, the

amount of frost and the quantity of covering snow in the activity layer. For instance, according to drilling results in the district of the I-t'u-li River, the general thickness of the activity layer on the sunny side is 2.0-3.0 m. and the thickness on the shady side is only 0.8-1.0 m. In the sides of the Chin River, the thickness is 2.3 m., but at I-chi-t'ai with the same kinds of soil the thickness is only 1.2 m., due to the continuous flowing of river water, which produces a certain heat capacity increasing the thickness of the activity layer. This type of underground water is distributed widely in the permafrost areas of Northeast China, especially at the foot of mountains where the activity layer is composed of clayey rocks with gravel, sandstones, crash stones and clayey syenite. The general thickness of the layer in different localities is listed as follows:

Two sides of river	Class 1-2 above T'ai-ti	Mountain foot and streams	Within forest	Ta-t'ou grass area	Ground surface covered w/snow of more than 0.2m
2.5-4.5m	1.5-2.0m	1.5-2.5m	2.0-3.0m	0.5-1.0m	1.5-2.5m

The principal source of underground water in these layers depends upon rainfall. Water quality is generally good, except in the lowlands and difficult discharging areas. We collected water samples for chemical analysis from the districts of Ken River, Chia-chung, Te-erh-pu-erh, Mo-erh-tao-ko, Chin-lin, A-li River, Ning-a, Wang-tzu River, I-tu River and the K'o-i River. The main items analyzed are:

Total Hardness (TF-Kuo°)	Total Alkalinity (degrees)	Evaporating Residual 105°C (Mg/l)	Mineral Residual 105°C (Mg/l)	HCO_3^- (Mg/l)	$SO_4^{=}$ (Mg/l)
2.0--5.0	2.5--6.5	100--250	50--150	50--120	10--20
Cl^- (Mg/l)	Ca^{++} (Mg/l)	Mg^{++} (Mg/l)	SiO_3^- (Mg/l)	Fe_2O_3 [illegible] Al_2O_3 (Mg/l)	pH[illegible] Value
< 50	10--30	5--15	8--20	5--10	6.0--6.8

From the above water analysis data, the water quality in these areas belongs mostly to carbonate salts in the form

of calcium. Other items in relation to water for technical use of railroad transportation and drinking purposes meet the standard requirements.

The most remarkable point about underground water in this layer is that it has a shallow buried depth, being merely 0.3-0.5 m. from the ground surface. The water in this layer is abundant and is collected by local inhabitants for daily usage. Generally, the best underground water of this layer is taken from a nearby river or lake that can be utilized during all seasons of the year. For instance, the river bed cross-section (Fig. 1) of the Ya-lin line x x River shows the permafrost layer where underground water is used for water supplies during railroad construction.

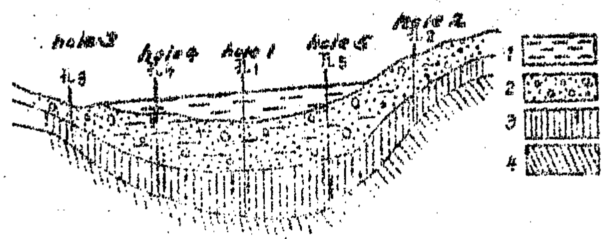

Fig. 1

1. Frozen layer of river water.
2. Sand-gravel, gravel and crash stones saturated with water.
3. Melting district of clayey rocks.
4. Permafrost layer.

In short, the underground water of this layer can supply water to small scale mining industry, seasonal lumbering, general investigation of geological minerals and fundamental engineering constructions. However, its possible unstable form should be carefully considered when underground water of this layer is used.

2. The mid-water of the frost layer: This is an underground water lying within the frost layer. It is not as extensively distributed as the upper water of the frost layer. It is related not only to the upper water of the frost layer, but also to the lower water of the frost layer. It is affected by both atmospheric temperature and ground temperature. Therefore, it can be either in liquid phase of in solid phase. Since the supply conditions are different, its physical character, chemical composition and vapor constituents vary accordingly. If it is supplied by the lower water of the frost layer, the temperature of the underground water will be higher and it will have a definite water pressure head. From analysis of its quality, this water is clean and pure and the quantity of water is comparatively stable all year.

If it is supplied by the upper water of the frost layer, the water temperature affected by the atmospheric temperature can have either positive or negative values. From analysis of its quality, this water is discovered to have unclean marks, and sometimes the water quantity decreases gradually conforming with seasonal freezing.

When preparing geological sections, we frequently could not reach the expected results because of the vague distribution of underground water in this layer. For instance, two drillings less than 100 m. apart at Ning-a railroad station were observed. One had no water, the other produced a great amount of water when the drilling reached the frost layer. Several wells drilled to 16 m. deep by the Operation Station of the Ministry of Forestry in the La-kou district did not show any water, freezing down to the rock-beds. We drilled to 26 m. deep in the same district and found no water. It was later discovered that this district lies in the axial part of a small island-shaped frost belt; therefore, no mid-water in the frost layer occurs. As another example, at the intersection of the Chin River and the Pei-la-erh River a geological section was prepared as in Fig. 2 and 3.

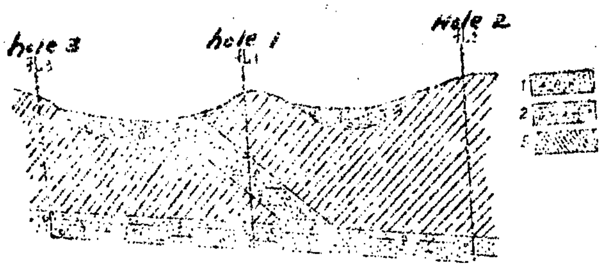

Fig. 2

1. Gravel. 2. Water and gravel. 3. Permafrost layer.
a. Upper water frost layer.
b. Mid-water frost layer.
c. Lower water frost layer.

Drilling holes 2 and 3 did not show any mid-water of the frost layer, but No. 1 produced a large amount of water, which steamed when pumped out. Therefore, this water is considered to be supplied by the lower water of the frost layer.

A general conclusion of our observations in these districts is that underground water in this layer does not widely occur.

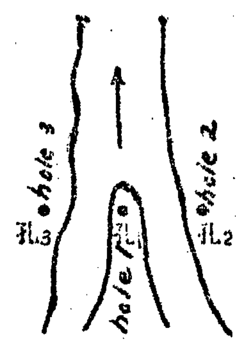

Fig. 3
Drilling top view.

In order to utilize underground water of this layer, it is necessary to understand thoroughly from the beginning its water distribution and sources. In preparing geological sections, the drilling space should not be too great and long periods of pumping experiments should be performed while the frost is reaching critical condition. Then the permanent water sources might be divided into poor, medium and rich according to the water's capacity.

3. The lower water of the frost layer (including the deep layer undercurrent): This is an underground water which lies under the frost layer. It is the most reliable type of underground water in permafrost areas and also the most significant type from the viewpoint of water supply. It not only has a large amount of water, but also has good water quality, which is not affected by atmospheric variation and ground surface contamination and which has a positive water temperature. It always exists in liquid phase which is not appreciably different from the underground water of non-permafrost areas. The only differences are that it has a non-permeable frost layer as its top which prevents water supply and discharging conditions and generally has a definite water pressure head. The underground water of this layer exists commonly several meters below the frost layer, but in some places it lies 20 meters under the ground surface. Chin-lin Station of the Ya-lin line needs a large quantity of water for technical use in transportation. To solve this problem, we should get the underground water below the frost layer. According to the following conditions, we predicted the possible existance of underwater in the frost layer at the Station:

(1) The station district is located in the axial part of a sedimentary basin between mountains and has a water gathering area of about 80-100 square km. Rain falls in the station district.

(2) The igneous rock clevages around the mountains are well developed by the abrasion of wind. Rainfalls run directly through the clevages into the ground to supply underground water for the deep layer.

(3) The Chin River passes near the station district. Observations of the river's flow rate upstream and downstream, 2 km. apart, indicated that the river supplies a large quantity of the underground water.

(4) A large piece of active icy hill near Pei-la-kou after two years observation, has the same activity position and area which are probably results of being supplied by underground water.

(5) The rugged ground surface with perpendicular cracks of frosted soil near the station district indicated

that underground water activity in this area has been very active in the past.

Based on the above conditions, with the aid of electrical analysis, we selected two deep drillings where underground water below the frost layer was found 50-60 m. under the ground surface. There is abundant water of good quality, having a water pressure head of 30 m. Therefore, it basically solved the water problem for that station.

The above three layers of underground water sometimes become a single underground water which varies in its form or position. The mid-water of the frost layer is an inter-movement passway of the upper and lower waters of the frost layer.

II. The season for reconnaissance survey.

Hydrogeological survey in permafrost areas can not be carried out all year as in other areas, because both soil and water melt or freeze as the seasons change. Therefore, the survey should be performed in the critical freezing season and the critical melting season. Generally, it is divided into two surveying periods.

The first period is in late winter when the water is frozen. The lowest temperature of the activity layer can be determined in this period. The flow rate of the springs and the lowest flow rate of the water-containing layer and the melting district can also be roughly determined by finding the position of the constant spring flow and the thickness of the frost layer. Such hydrogeological phenomena as icy hills and icy ridges are easily discovered. All this information enables us to select a more exact position for survey. The principal work of the survey should be immediately done within this period while the ground surface is largely frozen and is without traffic difficulty.

The second period is during the late summer and early autumn. During the first period of survey the ground is almost covered with accumulated snow, so that rocks are hard to find. For this reason the second period supplements the deficiency of the first survey period. The characteristics of permafrost are noted, the depth of seasonal melting is determined, the supply amount of maximum underground water time is recorded and the depth of the permafrost layer and melting areas is measured in the second survey period.

III. Several indications for hydrogeological investigation aided by the permafrost district.

1. Areas that are low and discharge water with difficulty usually become pondized. The pondized soil produces many tower-shaped grasses, which are water-favored plants.

se grasses supply temperature-preserve action to the nafrost. Therefore, a pondized district with towerped grasses is a good indication of a permafrost layer ng near the ground surface. Another indication is bushes, ally growing in the sedimentary layer. According to our ervations that bush district is an indication of a melting e. Hydrogeological investigation should follow the dirion of these bushes.

2. Areas where winter snow is easily melted or ulated snow is thinner and where spring melting is earlier winter freezing is slower, indicate underground water ivity, since the soil temperature is different from the ospheric temperature. Soil temperature is warm in winter cool in summer.

3. Underground water is generally active in wetted, ay ground, in the feet of mountains where water constantly rruns, or in places that never crack, even in a drought son.

4. Areas that have icy ridges, icy rock or hilly und splits and where water overruns from ice indicate y active underground water activity.

5. In winter, river water usually approaches zero rees. Areas where water temperature is higher probably icates underground water supplying water to the river.

6. Areas with completely frozen surface water, having e animals than usual, usually indicate the spots where erground water overruns.

7. On winter mornings, frogging and a thin layer frost on the tips of the trees indicates an area having erground water activity.

8. Areas with falling-leaf pines and bushes growing icate permafrost districts. The frost layer is close to ground surface. Areas with water-favored plants growing ng a river indicate the existence of a melting district. depth is near the ground surface.

9. Areas that have bent trees indicate the presence icy rocks and ridges. Areas that have wind-blown trees icate a permafrost layer near the ground surface.

Several cautions for hydrogeological investigation in permafrost districts.

1. Prior to drilling, the depth of the frost layer uld be estimated and necessary arrangements made. Attention uld be paid to temperature preservation of the hole while lling is discontinued. Generally, straw bags or cotton covered over the hole to prevent freezing of the hole l which would retard the drilling progress the next day.

2. During drilling it is very important to determine upper and lower limits of the frost layer. Drilling should

be done in the center to avoid icy fragments falling into the water causing a leakage layer to form. The limits can be determined by the changing speed of the drilling and by cooling when the drill head reaches the frost layer.

3. The bushings should not stay in the frost layer too long. They should be taken out when the drilling is finished to prevent the hole from freezing. The drilling equipment should not be kept in the hole overnight.

4. To observe the underground water level beneath the frost layer is very complicated, because the underground water of this layer usually has a definite water pressure head which is frequently stablized above the lower limit of the frost layer. The water in the hole is generally frozen. Therefore, besides a tent covering over the drilling hole it is necessary to keep the hole constantly warm by a heating system.

5. When drilling reaches a very thick frost layer, the drilling speed should be very low. A boiler should be installed to produce boiling water or steam which passes through the rubber tube into the hole to increase the drilling speed.

6. During pumping tests, all equipment should be kept in warm places such as a tent or a temporary straw room. After pumping, the remaining water in the pump should be poured out to avoid damage by freezing.

7. During the pumping experiment, the water level stablizing period should be continuously kept at 4-6 days. The experiment should be performed under critical freezing conditions to assure the reliability of the water source.

8. During hydrogeological surveying and plotting, the benchmarks are displaced horizontally and vertically because of periodic freezing and melting of the soil. For this reason, the benchmarks should be put 0.3-0.5 m. deep into the permafrost layer and this should have triangle-shaped ends to prevent horizontal displacement.

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ON THE APPLICATION OF MUD DRILLING IN SUPPLY-WATER HYDROGEOLOGICAL EXPLORATION

/Following is the translation of an article by the Ministry of Construction and Engineering, in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 16-20./

Introduction

The sole characteristic of mud drilling is to bore a hole without using a bushing. The mud drilling method adopted in the hydrogeological survey for water supply not only solves the problem of the lack of bushings, but also speeds the progress of survey. By this method, a hole of a larger diameter can be drilled and a bigger size filter pipe can be used, thus promoting the survey quality and uniting production. However, this method is not easy to apply because of technical difficulties with the mud around the hole. In order to obtain more successful results, these technical difficulties must be solved.

Since 1957 we have been researching on these technical difficulties and the results of research indicate that it is very possible to overcome the difficulties in the mud drilling method.

The content of our research consists of (i) mud index, (ii) drilling method, (iii) using a rock center, (iv) determining the static water level, (v) comparing results of well washing and water-pumping tests and (vi) layer sealing. The results of our preliminary research for some of the above topics are presented as follows:

I. Water-pumping test results of mud drilling.

1. Well washing by a piston.

The accuracy of the test is closely related to the completeness of well washing. Therefore, it is necessary first to discuss the problem of well washing.

A piston inside the filter pipe is used for well washing

in the mud drilling. The piston moves up and down to break the clayey wall in preparation for washing the drilling hole. When the piston in the filter pipe goes down, it opens the valve; the piston is raised immediately when it reaches a certain position in the water layer. By close contact between the piston and the filter pipe, this action produces a suction which assists underground water in breaking the mud wall and which brings the mud, together with fine grains from the ground layer, into the filter pipe. When the piston is raised to the top of the water layer, it is suddenly released. A striking force of underground water to the mud wall is created by the moment of the initial action. The repeated action of the piston can break the mud wall completely and satisfactorily wash the boring hole. The accomplishment of well washing by a piston can be proved by physical phenomenon in a field experiment. (1) Well washing by a piston can obtain more volume of sand from the filter pipe than well washing with any other equipment. For example, in Kung-chu-fen district west of Peking, with a water layer over 10 m. thick (sand-gravel), the sand volume taken out of the filter pipe was about 1 m^3 ; at Ching-tao, with a water layer of 7-8m thick (sand-gravel), the sand volume reached 0.5 m^3. These conditions could not have existed if the mud wall had not been completely broken. It illustrates that a better artificial filter layer was formed around the filter pipe. (2) After well washing by a piston, there was no sand or little sand in the filter pipe during the water pumping test. For example, after 144 hours of continuous pumping in a suburb west of Peking, a little sand was found in the filter pipe. This condition could not be obtained except by effective well washing. (3) The unit flow rate and permeability have no effect with respect to the relative size of the bushings. The unit flow rate and permeability are greater when not using well washing by a piston, which further illustrates the effect of well washing by a piston. This will be further explained in detail below.

In order to better understand the action and effects of well washing by a piston, a simple model experiment was performed in a laboratory. A model 50 cm high, 60 cm wide, and 80 cm long, having water tanks 10cm long at both ends, with plywood covers on the hole openings was made. A 3" filter pipe wrapped with copper sieve was installed in the 60 cm side and then filled with various graded samples (sandstone, sand-gravel); water was allowed to flow from the tank through the samples. A small scale piston was used to move up and down mannually in the filter pipe. It could be seen that grains within 6-7 cm of the filter pipe were greatly disturbed, and the disturbance was greater near the

filter pipe. Upon each movement of the piston, the grains changed their position quickly. Meanwhile, the fine grains were sucked into the filter pipe. After about 6 hours of piston movement, the grains in the sample, though they continuously changed their position, were no longer sucked into the filter pipe, and its influential area no longer increased. It was found that, after well washing by the piston, there were no fine grains within6-7 cm of the filter pipe, but coarse grains with greater void ratio due to the severe disturbance. Table 1 shows the sample results at different distances from the filter pipe. The diameter of the copper sieve outside the filter pipe is 1 cm.

Table 1

No. of Test	Sampling Location	Graded Grains %				
		>10	10-4	4-2	2-0.5	<0.5
1	Within 6-7 cm of the filter pipe	37	40	4	18	1
	10-11 cm away from filter pipe	3	17	5	71	4
2	Within 6-7 cm of the filter pipe	38	45	4	13	0
	10-11 cm away from the filter pipe	2	16	6	72	4

The experiment results illustrated that within 6-7 cm of the filter pipe all grains smaller than 1 cm had been completely sucked into the filter pipe.

A model experiment to determine the effectiveness of well washing by a piston in a mud hole was also done by placing a 5" bushing in the previous model, filling in with samples outside the bushing, then pouring liquid mud with specific gravity of 1.3 in plaster form (it is the worst condition for well washing by mud), and finally, taking out the 5" bushing without sliding phenomenon at the hole wall. After about 40 hours, the liquid mud around the circumference of the boring hole became a muddy wall. A rubber tube was inserted at the bottom of the filter pipe to gently introduce water for back washing. Within an hour the effluent became muddy water, the muddy wall not being damaged. Then, well washing was done using a piston for a little over 10 minutes, and the muddy wall was completely damaged. Similar testing conditions were observed when sandstones were mixed with mud and placed under piston movement for 8-10 hours.

These experiment results concluded the following: 1. The circumference of a filter pipe is a better artificial filtration layer not obtainable by other well washing equipment. 2. Well washing by a piston produces a great disturbing

force in the ground layers; the closer the filter pipe, the greater the force. It has a definite influential area which does not increase as the extent of time of well washing increases. Therefore, it is best to obtain the well washing standard in the field when there is no sand sucking into the filter pipe. 3. The same results are obtained by using this method for a mud hole; however, it takes a little longer.

There are various types of pistons that can be used; the type that we used is shown in Fig. 1. A proper diameter of the piston is necessary; a too small diameter will affect the results and a too large diameter will choke the grains and cause an accident. The piston can be operated either by a drilling machine or by manual power. Manual operation is not suitable for a deep hole. During operation, it is better to separate the water layer into sections of 1-2 m deep each, and work each section separately working from the upper water layer downward. While well washing, it is troublesome work to take out sand from the filter pipe; we used a flat bottom cylinder which provides more than double efficiency as compared to the general pumping cylinder. It hould be noted in well washing by a piston that, since a large amount of fine grains in the ground layer are sucked into the filter pipe, the backfill sandstones should be a few meters higher than the top of the water layer to prevent the collapse of the layers between the water layers.

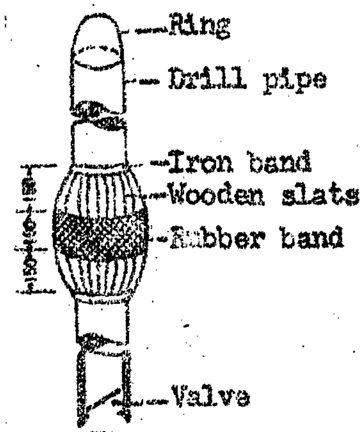

Fig. 1
Mud hole piston.

In short, before applying well washing by water pumping, well washing by a piston is a very accurate method that assures the amount of flow rate into the mud holes. Moreover, it is a very simple operation. Because it can form a better artificial filter layer around the filter pipe, this method is applicable to bushing drilling, too, and should be widely used.

2. Comparison of water pumping experiments by mud hole and bushing hole.

Table 2 is a brief description of each comparing group.

Table 3 is an outline of water pumping tests of each group.

Table 4 is a water analysis of each group.

Table 2.

Group No.	Location	Location Marker	Hole No.	Drilling Method	Dia. of Filter m/m	Pumping Equip.	Water Level
1	KUNG CHIH WEN WEST SUBURB PEIPING	180M ↑N 115 114	115	BUSHING УКС—20	136	CENTRIFUGAL PUMP	1
			114	MUD КАМ—500	134	"	
2	KUNG HUI BLDG WEST SUBURB PEIPING	↑N 306 137 136 200M 150M	306	MUD КУС—20	134	"	1
			137	MUD КАМ—500	134	"	
			136	BUSHING КАМ—500	134	"	
3	28TH MIDDLE SCHOOL WEST SUBURB PEIPING	163A ↑N 2.5M 163M	163M	BUSHING MANUAL	146	"	2
			163A	MUD KA—2M —300	146	"	
4	TAI HSING DYE-STUFF PLANT. PEI HSING CHIN SHANGHAI	↑N 6B 18M 6 6A 12M	6	MUD УКС—22	141	AIR COMPRESSOR	1
			6A	MUD УКС—22	150		
			6B	MUD УКС—22	150		

Table 3.

GROUP NO	HOLE NO	DRILLING METHOD	WATER LEVEL	DEPTH OF THE WATER LEVEL	S (Meters)			Q (Litre/			q (Litre/ Sed. M.)			T (Meter/24 Hrs.			
					S_1	S_2	S_3	Q_1	Q_2	Q_3	q_1	q_2	q_3	K_1	K_2	K_3	KCP
1	115	B	1	21.44	0.35	0.66	1.37	7.28	12.20	21.11	20.79	18.48	15.45	113.1	101.3	86.1	100.2
	114	M	1	27.43	0.62	0.35	0.19	22.61	13.46	7.45	36.59	38.56	40.04	156.4	164.0	168.8	163.1
2	306	B	1	15.30	1.00	2.00	3.00	1.57	2.53	3.22	1.57	1.27	1.07	11.9	10.2	8.9	10.3
	136	M	1	6.98	2.37	1.64	0.63	21.74	17.42	8.24	9.18	10.64	13.18	183.0	200.0	229.0	204.0
	137	M	1	14.74	0.62	1.28	1.97	9.71	18.72	26.65	15.70	14.63	13.51	126.0	120.0	114.0	120.0
3	163M	B	1	4.53	0.81	1.56	2.35	0.82	1.40	1.67	1.01	0.90	0.71	24.7	21.7	17.3	21.2
			2	7.05	2.07	3.10	3.98	4.32	6.14	7.74	2.09	1.99	1.95	32.5	30.8	30.2	31.2
	163A	M	1	5.25	1.54	2.78	3.73	2.02	2.95	3.29	1.31	1.05	0.88	27.3	21.9	18.4	22.5
			2	7.35	1.20	2.40	3.37	4.77	8.37	10.64	3.97	3.48	3.16	59.2	51.9	47.1	52.7
	6	B	1	24.40	2.24	—	—	12.82	—	—	5.74	—	—	23.5	—	—	—
4	6A	M	1	24.50	2.50	3.98	4.94	12.82	20.33	24.43	5.13	6.08	4.96	20.7	20.5	20.0	20.4
	6B	M	1	23.57	3.50	—	—	17.18	—	—	4.91	—	—	20.6	—	—	—

[Note: B=bushing, M=mud]

Table 4.

Group No.	Hole No.	Drilling Method	Water Layer	Important (Mg/l) Separated Residual					pH
				Ca^{++}	Mg^{++}	$SO_4^{=}$	Cl^{-}	HCO_3^{-}	
1	115	Bushing	1	82.2	30.0	40.9	32.5	336.4	7.0
	114	Mud	1	79.1	29.9	28.2	29.8	317.8	7.6
2	306	Bushing	1	105.2	43.6	93.7	69.3	401.5	7.6
	137	Mud	1	108.2	40.6	97.2	73.9	415.7	7.5
	136	Mud	1						
3	163A	Bushing	1	181.4	65.4	168.6	167.0	627.9	7.1
			2	148.5	79.4	195.6	158.9	631.5	7.0
	163B	Mud	1	168.5	73.1	174.4	172.3	63[illegible].5	7.1
			2	156.7	83.3	163.6	161.7	621.2	7.1
4	6	Bushing	1	358.0	94.2	2.6	113.6	365	7.8
	6A	Mud	1	297.3	98.7	1.8	95.0	282	7.9
	6B	Mud	1	340.3	106.9	2.4	112.5	308	7.6

First group; The distance between the mud hole and the bushing hole was 180 m. Ground layers were generally similar. The average grain gradation was as follows:

Hole No.	Drilling Method	Grain Gradation					
		<10	10--2	2--0.5	0.5--0.25	0.25--0.1	<0.1
115	Bushing	62	17	6	3	0	2
114	Mud	63	12	19	5	4	1

The K value of the mud hole was approximately 60% greater than that of the bushing hole, because well washing by a piston was applied to the mud hole. The bushing hole was not well washed by a piston and it was well washed in limited production time. The well washing being done by water pumping for only 3-4 hours, the bushing hole was not completely washed.

Second group: The result of the water pumping test evidently was not accurate. The permeability of the bushing hole was 90% less than that of the mud hole. It seems impossible to have so small permeability at Fu-hsing-men district in the west suburb of Peking (this hole will be done again in 1959) with such a great difference of two holes. The principal reason is that there is an intermediate clayey layer with sandstones between the water layers. At No. 136 drilling hole, it was considered two water layers; during the testing, the second water layer was sealed. Actually, it may only be one layer which cause a great deviation in

the results.

Third group: The distance between the mud hole and the bushing hole was 2.5 m. It was noted that the bushing hole, without applying well washing by a piston to it, will affect the flow rate. Therefore, well washing by a piston was made in both the mud hole and in the bushing hole. In the first water layer experiment, both holes had the same permeability. In the second water layer result, testing in the mud hole created a deviation because its sealing work was not properly done. The mud hole should have been sealed both inside and outside of the pipe, because the working part of the filter pipe reached two water layers. Water sealing can effectively be done by wrapping the outside of the pkpe with sea plants. Inside the pipe, a water sealing pipe with a diameter of 127 mm., wrapped with sea plants, was inserted (this hole applied water pumps, the outlet pipe not replacing the water sealing pipe; if a water sealing pipe with a diameter less than 127 mm is placed with a smaller outlet pipe, the flow rate in the drilling hole will be affected). Because the space between two pipes was too small, water-sealing ability was poor which caused the mud hole to have a greater deviation value.

Fourth group: The distances between the mud holes and the bushing holes were 12 m and 18 m respectively. The bushing hole also was operated with well washing by a piston. The permeability of these three holes were basically the same (hole #6 and #6B did only once during the water pumping tests because they were limited by the capacity of the air compressor).

Though the number of the relative groups was not large enough for comparison, though the distance between holes was too far apart, and though the conditions of technique and the equipment were not strictly the same, the above experiment results revealed that there was no affect in the water pumping experiment after the mud hole had performed well washing by a piston. The two mud holes in Group 4 had the same results which indicates further the point. In 1959, at Peking, a comparing group was experimented with. The distance between the bushing hole and the mud hole was 2 m with similar basic conditions of technique and equipment. The preliminary result of this experiment was no different (still under testing). This also pointed out clearly that an accurate result could not have been obtained if well washing of the bushing hole had not been properly performed. It should be especially noted and suggested that from now on all bushing holes should operate well washing by a piston to assure better quality and quantity.

From the water quality analysis of each group, mud drilling has no inferior affect as far as the water quality is concerned.

II. Using a rock center mud hole.

We are concerned with the problem of whether or not we can get a water sample without mud in the water layer of a mud hole, because it is a necessary datum for our investigation. Before discussing this problem, we will introduce a little information on the model experiment results of permeability of mud in the ground layer of mud drilling, because this experiment has great significance for using the rock center in determining the water level and in well washing.

An 8"Ø pipe is used to form a model of Chi-niao-shih permeability equipment, 1 m. high; the pipe is filled with various graded samples (about 50 mm in each experiment); water is poured into the top to saturate the sample and the water level is allowed to be stable above the sample. Liquid mud with a specific gravity of 1.10 and viscosity of about 20 sec. is added on the sample and then, a pressure of 0.5-2.5 kg/mm is applied on the pipe through a piston on the mud surface. After pressure has been applied, water begins to permeate out through the sample (actually most water flows out along the pipe wall) for about 20 minutes and then stops. After 45 minutes of continued pressure, a mud cake of 1.0-1.5 mm thick appears, when the model is opened. The boundary line of the mud penetrating into the sample is not clear; its maximum permeability is less than 2-3cm and the penetrated mud is diluted into liquid mud by water from the sample. Though the model can not exactly reflect the actual field condition, it at least shows the result that during a drilling survey, the liquid mud can penetrate only to a limited depth into the ground layer. This conclusion is in agreement with the Russian expert, Professor "Ko-li-men-to-fu"'s, " . . . mud has little affect on the rock layer", from page 93 of "General Surveying Hydrogeology".

In practice it is possible to obtain samples free from mud by rotary drilling with the continuous press-in method using ball rock-center pipes. When drilling reaches the estimated depth, the pipe is placed into the bottom of the hole to close the mud pump. This stops mud circulation in the boring hole and controls it. The pipe is pressed continuously. When rock sample comes into the pipe, it replaces the same volume of liquid mud in the pipe by action of the ball, and the liquid mud leaves through the discharging hole. As it enters a certain depth (based on sampling requirements, generally 30-50 cm), the drilling rod is raised so that the ball comes back to its original position in the pipe. This not only prevents the liquid mud from entering, but also bears mud pressure in the hole. The rock sample is sucked without falling when the drilling rod is raised because the rock center pipe contains a vacuum when the pipe is pressed-in and because there is a buoyancy force of the liquid mud.

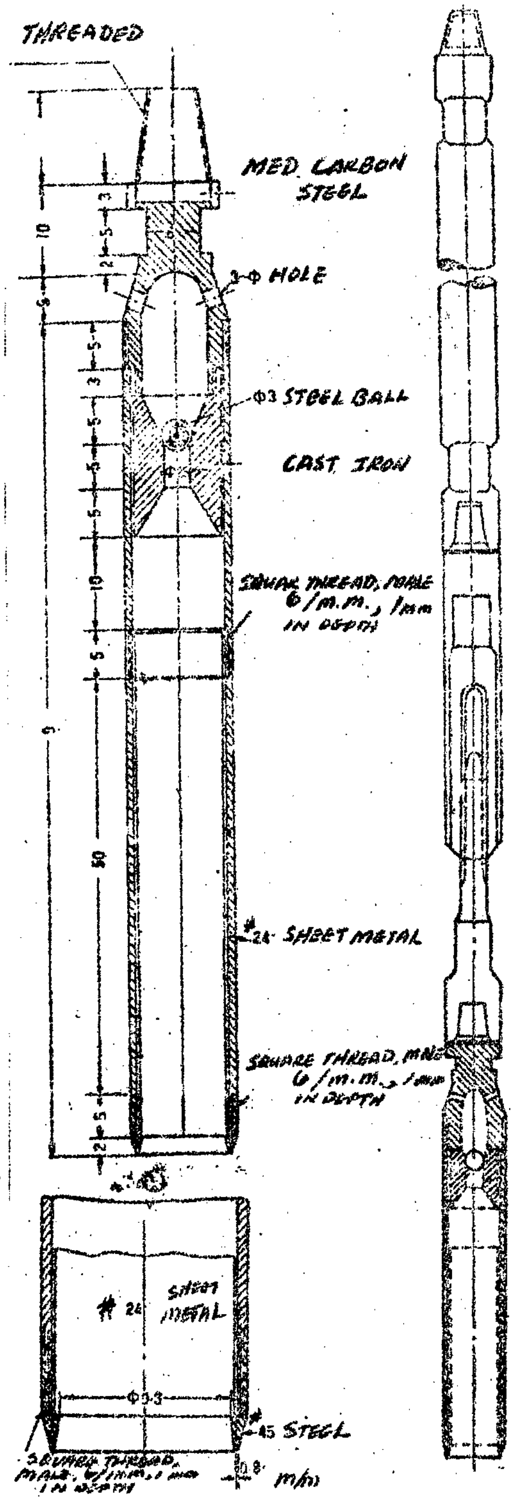

Fig. 2 Collector

In a west suburb of Peking, it is possible to obtain rock sample of grain size 10-30 mm. and containing over 75% in the ground water layer. Except the end portion of 3-5 cm containing mud (this is the permeability of liquid mud in the ground layer), the rock samples obtained by this method were free from mud and met the quality requirements.

The drilling of the striking type takes samples by a movable collector (Fig. 2). The principle of this type is similar to that of the previous one. The bottom of the hole is cleaned when drilling reaches the designated depth for sampling. The collector is put into the hole and is held by a rolling cylinder at a distance of 1-2 m above the bottom of the hole. The rolling cylinder is suddenly released so that the collector hits the ground layer with such a force that it will penetrate to a certain depth of the layer. This method can not only speed the sampling progress, but also can fix the position of the collector to assure a better quality. Then the steel rope is raised to a certain height (it should be less than the moving distance of the collector, the greater the moving distance of the collector, the better the result; the distance actually used in Shanghai was 70 cm). The rolling cylinder is quickly released again to produce a gravity impact for the collector. The required samples can be obtained by the repeated striking operation. The samples obtained from the mud hole in Shanghai are shown in the photograph below:

(Photograph not reproduced here because of poor quality)

In the Shanghai district there are generally more clayey soil grains mixed in the water layer. Their size is commonly less than 0.1 cm and over 20% water content. By using a pumping cylinder for sampling in a bushing hole, the fine grains (less than 0.1 mm) can hardly got into the cylinder. From the above data, it is understood that samples with less than a 0.1 mm grain size from a bushing hole are much smaller than those from a mud hole by the mud collector. Fine grains exist in ground layers. Using the sieve analysis results to design filter equipment is evidently unreliable. During a water pumping experiment in the district of Shanghai, a large amount of flowing water that affected the test result and caused an inaccurate sampling frequently occurred. Another example, in the Cheng-tu plain investigation, where the ground layer is gravel mixed with clayey soil, the K value by the permeability test in the laboratory was many times greater than the K value by the water pumping test. After repeated checking, it was found that the ground layer consisted of a certain amount of clayey soil which could not be sucked up by a pumping cylinder in a bushing hole. This caused the greater value for permeability tested in the laboratory.

Based on the experimental results, except those ground layers containing much big gravel, rock sampes of good quality can be obtained by both the rotary drilling type and by the striking type, especially in ground layers containing much fine grains. For ground layers, samples from a pumping cylinder can not give very accurate results. The representability of these samples is a question of the necessity of practical work, especially in unevenly graded grain in ground layers where samples should be taken by a soil collector to assure the quality.

Table 5.

Sample No.	Depth (in meter)	Method of collecting	Grade of grain 10–2	2–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.005	< 0.005
7	78.15 —78.70	Mud hole collector	7	22	17	11	9	22	12
8	78.00 —80.00	Bushing hole pumping cylinder	26	32	24	9	0.1—0.06=9		
4	80.00 —80.20	Mud hole collector	5	9	15	17	18	23	12
9	80.00 —80.20	Bushing hole pumping cylinder	13	52	25	9	0.1—0.08=1		

III. Determining the static water level in a mud hole.

At present, we can determine only the static water level in a mud hole; actually, the static water level is the main factor in supply-water hydrogeological survey. In practice two methods are adopted; they are theoretically the same. According to both methods, a water-level test pipe is placed in the mud hole and pressed into the ground layer to a certain depth, the liquid mud outside the test pipe being kept away. Then, the fragments and mud in the pipe are taken out, and mud pressure is eliminated in order to determine the static water level in the pipe.

The method of using well striking: When the pipe reaches the estimated water level, the bottom of the hole is cleaned and a 2"Ø test pipe with small holes around it (void ratio about 15%) is put about 20 cm from the lower end and is struck into the ground layer to a certain depth. Then, a 3/4"-1" pipe is inserted into the 2"Ø pipe to act as a striking rod with a valve drilling head at its lower end and as a striking handle at its upper end. During striking the rock fragments can be brought up from the hole; the 2"Ø pipe is lowered to a depth of over 50 cm below the original hole bottom. A 2" manual pump is installed to pump out the mud in the 2"Ø pipe (when the mud is too concentrated, it is diluted with water first) and the water in the water layer is pressed into the pipe. After the hand pumping is stopped, the static water level can be observed in the 2"Ø pipe. By using this method, a comparison of the static water level of the bushing hole and the mud hole 2.5m apart was made by Group 3 in Peking, as listed in Table 6.

Table 6.

Hole No.	Drilling Method	Static water level	Date of survey	Surveying instrument
163H	Bushing	4.906	57.10.27	
163A	Mud	4.890	57.12.21	

Table 6 indicates that the static water level determined by this method is reliable; it is a simple method in equipment and in operation. However, this method applies only to hole depths not over 60-80 m and to drilling holes of shallow ground water level (within 10 meters below ground surface).

Method of using a 4"-6"Ø pipe as a water level test pipe: The pipe is struck into the ground layer to a certain depth; with the aid of a pumping cylinder or a soil collector,

the pipe is lowered to more than 50-80 m below the ground layer. The outside of the circumference of the pipe is filled with a clayey ball to prevent mud from entering into the pipe; the mud inside the pipe is taken out (meanwhile, the mud surface in the drilling hole should be watched to see if it is lowering; lowering means that mud is leaking, and an immediate remedy is required), and then the static water level can be observed in the test pipe. This method has the problem that during striking of the pumping cylinder to lower the test pipe it produces a vacuum suction which easily breaks the ground layer and affects the quality. Therefore, it is better to use a soil collector to lower the test pipe to solve this problem and to obtain samples and water level simultaneously. Besides, a soil collector can determine accurately the grain graded condition of the observing water level in the water layer. As a matter of fact, it is hardly possible to take out all the fragments, especially in a flowing sand layer. In addition, the sediment mud so greatly retards the up-rising velocity of the underground water that more time is required to determine the water level and the quality is affected. This will be further studied in our hydrogeological survey.

Conclusion

Application of mud drilling in water supply by the hydrogeological survey has been materially realized in accordance with our party's policy of walking on two legs. The application is an effective wy to solve the present lacking of bushings and to speed up the progress of survey. Since there is much to be done, it is necessary to invite more people to participate in research on this subject.

However, there is a disagreement at present. Some comrades believe that the mud drilling method can not assure its quality; we think they are wrong because they have not understood mud drilling. Though there are not many experiments, and though problems remain to be properly solved, the results of the above preliminary studies have shown the application of mud drilling in water supply by the hydrogeological survey. We can only study earnestly, solve all technical problems and assure better quality. Some problems have been solved; some qualities obtained by mud drilling are better than that obtained by the bushing drilling. If all of us study and work hard, all technical problems can be perfectly solved and an overall assurance can be made to both the quality and the quantity.

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SOME EXPERIENCES IN USING MUD TO CARRY OUT HYDROGEOLOGICAL BORING TO RAISE THE QUALITY OF THE BORE HOLE

/Following is the translation of an article by Li Pao-hsing (2621 1405 5281), in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 21-22./

When mud drilling is adopted in hydrogeological boring, the quality of the bore hole usually is not high. The principal reason is lack of study and experience. We discovered an idea from our practical experiences (mainly in thick big gravel layers) to improve the quality of the bore hole using mud drilling. This idea is described below for your reference:

I. Applying boundries in mud controlling.

1. Mud drilling should not always be applied where water drilling is applicable. Water drilling can be applied to a sandstone layer, to sand and sand-gravel with a large amount of clay, or to a gravel layer of low hardness.

2. In a boring hole, mud application should be strictly controlled. Mud drilling can be used after the hole is opened where the underground water level is generally deep; the density of the mud can be high in order to protect the hole wall and to speed the progress. Meanwhile, it is not necessary to place a bushing in the hole. Mud drilling can be applied 10-20 m above the estimated underground water to mud of low density to reduce the sealing capacity of the water layer. Water should be used instead of mud at the section where underground water might be discovered (about 10 m above the water level), since underground water level can hardly be discovered during mud drilling. After the underground water level is clearly determined, mud drilling of low density should replace the water until the designated depth is reached. This method is used mainly to speed the drilling progress, to assure the quality of the bore hole and to save a certain amount of bushing. Water drilling is

not applicable to the section above the underground water activity because it will slow down the progress and will not protect the hole wall. In order to assure the most effective performance of the above method, it should be noted that (a) prior to the hole layout, the drilling design and the determination of the drilling method, a careful study should be made of the local data, such as an accurate estimation of the underground water level, the design of the hole depth and the proper position to place the pipe, etc. and (b) during drilling, the designated steps of changing from the application of mud and water should be followed and the underground water level should be carefully watched.

II. The hole washing method after the completion of drilling.

After completion of the mud drilling, the bore hole's bottom and wall should be washed immediately for a lengthy time by powerful washing equipment. The sole purpose for the washing of the hole is to wash away the mud which is solidified around the wall. This method has generally been adopted by every field team. However, the quality of bore holes have not actually been improved because enough has not been known about hole washing and the progress has been affected. Bushings should be placed in the hole before washing; a filter pipe should be inserted in the water layer; and hole washing should be powerfully done for a lengthy time with washing equipment. The water pump should run at its full capacity while the washing equipment repeatedly moves up and down until all the mud in the bore hole has been cleaned up. The cleanliness of the hole can be determined by observing the mud concentration of the washed water; the degree of mud remaining on the hole wall can be determined by a tubidity meter. Under insufficient filter pipes, a double washing can be applied after completion of the drilling. First, all bushings are put in and only the bottom of the hole is washed. A water pipe is inserted during pumping and the bushings are taken out. Then, the hole is washed or long pumping is applied to wash the mud out of the water layer. The washing equipment is made of a drilling rod with some modifications; the holes and the distance between holes are based upon the actual situation. Many holes of small size produce a weak force but an extensive area; few holes of large size produce a strong force but a limited area. In a gravel layer, few quincuncial holes of large size are more effective to use; in a sand layer, many quincuncial holes of small size are more effective. When washing the bottom of the hole, water can be transported directly from the drilling rod without using the washing equipment.

III. The mid-way hole washing method.

By this method, a suitable section where drilling can be stopped is selected, and filter type bushings are put in the hole for washing until the water level datum is obtained for continuation of the drilling (hole washing should be made several times, if several water layers are met). The principal object is to understand the underground water level and the water layer condition to determine the depth of the hole and the bore hole's structure. When the underground water is deep and the water level is uncertain, it is difficult to design the hole depth and bore hole structure.. Conditions for applying the mid-way hole washing method are: (1) the underground water is deep and hole depth has not been determined; (2) two or more water layers may be discovered in a bore hole, and the water level of each layer has not been determined; (3) though there is only one water layer in the hole, the layer appears very thick and the water level can not be easily determined.

The requirements for applying the mid-way hole washing method: (1) before drilling is started, a bushing of the filtering type should by prepared (a bushing without wire wrapping and having a void ratio $<30\%$); (2) the density of the mud for drilling should be properly controlled in accordance with Section 1, Article I; (3) detailed research data and careful planning are necessary to better estimate the underground water level and to design the working drawing for drilling. This is especially important for hole drilling in several water layers.

Understanding the static water level is very important during hole drilling, especially in a bore hole of several water layers; the water level of each layer is most important to be understood. Based on the water level data, the hole depth and its minimum diameter at the bottom can be reasonably determined. The water layer sealing and pumping design can be applied to the foundation of each water layer. At present an air compressor is usually used for deep hole pumping by the hydrogeological teams. This kind of pumping machine is directly related to the underground water level, i.e., it is a proportional relationship. Therefore, in order to assure the pumping the hole depth becomes a fold function of the water level. Under the other conditions, the hole depth can be reasonably designed on the basis of the water level and it is the best way to eliminate wasting.

The drilling depth is equal to 2 times the static water level plus the maximum water level dropping:

$$H = 2h + S_{max}$$

where H is the drilling depth to be determined in m.
h is static water level after hole washing in m.
S_{max} is the designed max water level dropping during pumping in m.

Experience proved that the hole depth can be slightly less than the calculated value, but it will not be ideal when pumping. This is because the buried depth of the ventilation pipe can not satisfy the relationship of mixing the ratio.

For example, after mid-way hole washing the static water level in the hole is 53 m; the designed maximum water level dropping during pumping is 10 m; then the hole depth can be computed as:

$$H = 2 \times 53 + 10 = 116 \text{ m}$$

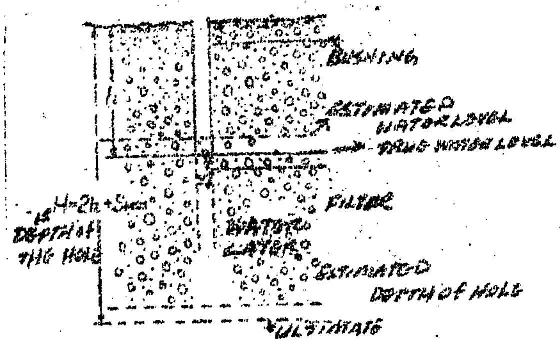
Therefore, the hole depth is determined as 116 m; its end hole diameter should not be less than 130 mm; so a 127 mm filter pipe is used.

The hole drilling of this method is similar to others; the only difference is that it can be stopped anywhere in the hole during the drilling, and then bushings of the filtering type can be put in place for hole washing. When the static water level is obtained, drilling continues until the next water layer is discovered. The process of hole drilling is repeated after another static water level is reached. The density of the mud can be higher in the beginning so that the mud can be used for widening the hole. The mud density should be low at about 10 m above the estimated underground water surface; the density should be high again when the water layer is passed through. The bushing should be placed several meters beneath the bottom of the water layer. Hole washing is performed by the washing equipment moving up and down repeatedly until the hole is cleaned. Then the static water level is observed and the stable curves of the static water level are plotted. Drilling is continued by using the next smaller drilling equipment to the next water layerand the hole is washed according to the same procedure as outlined above, using a bushing. Similarly, drilling can reach the designed depth of the hole. If a large, thick gravel layer occurs after the first hole washing, the underground water level not being discovered, another hole washing process should be done to a suitable depth below until the water level datum is obtained.

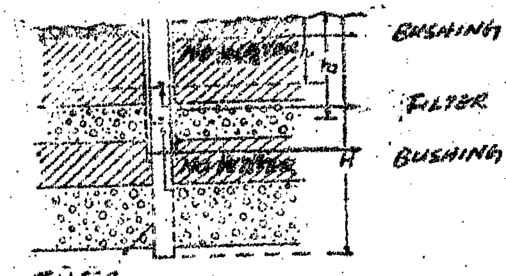
Adoption of this method not only can raise the quality of the mud hole but also can increase the efficiency of the hydrogeological boring.

The figures below are the designated sections of a

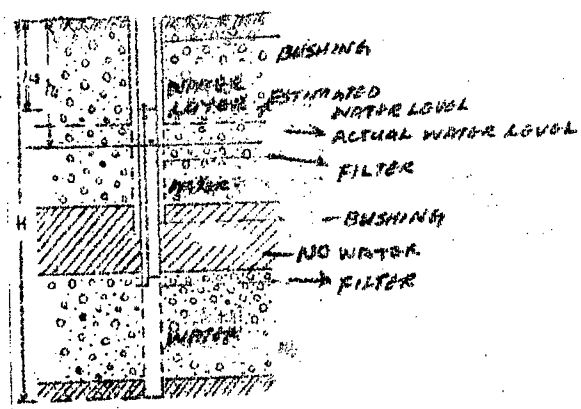
drilling hole having undergone the washing process under several different conditions.



A



Б



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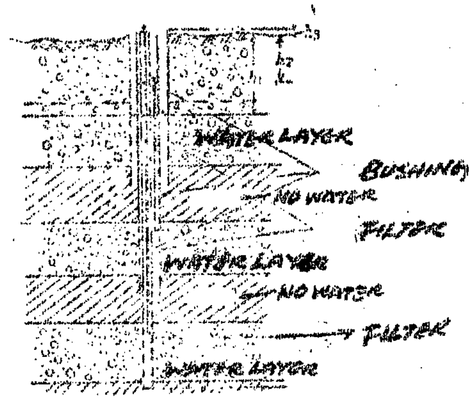

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A - A large, thick gravel layer.

Б - Two water bearing layers (each can be computed separately by mixed water pumping, because h and h are known; each layer can be calculated by the water pumping method).

B - Two non-water bearing layers. (A water bearing layer can be computed separately by each water layer or mixed water pumping).

r - Three water layers (can be computed separately by each layer or by mixed water pumping).

Remarks: (1) The bushing of filtering type can be used as a filter pipe in a large gravel layer or in a sandstone layer with more gravel.

(2) The bushing of filtering type can be used as a filter pipe in a surveying hole, but not in a producing hole because it will be choked by large amounts of sand flowing into the pipe.

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BUSHINGS AND THE PROTECTIVE WALL OF MUD IN A BORE HOLE

[Following is the translation of an article by Ch'en Ying-lung (7115 2503 7893), in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 23-24.]

According to past experiences in hydrogeological survey, each set of bushings can protect only a 30-40 m boring wall. If a hole weighing more than 30 tons is to be drilled 160 m deep using bushings for wall protection, a total length of 400 m composed of bushings with 8", 10", 12" and 14" diameters is required for one hole. Hydrogeological survey in our country is expanding every year; our industries and agriculture are developing and need more underground water surveys in the deep layers. To meet these requirements, deep holes will be drilled that require a large amount of bushings with large diameters. However, our country lacks bushings with large diameters. Under present conditions, most hydrogeological drillings need bushings to protect the wall of the boring hole. Therefore, it is a very urgent and important mission for our hydrogeologists to find a proper economical method for boring with the hole wall protected, reducing the amount of bushings, increasing the revolving application of bushings and eliminating the need for bushings with large diameters in hydrogeological deep drilling. For these reasons, this article presents a wall protection method for boring a hole by using bushings with mud (abbreviated as the combined method), for your reference and comments.

The description and procedure of the combined hole wall protection method.

To understand this method, an example is introduced for reference. A hydrogeological survey will be performed in the district of a sedimentary layer for water supply to a city. According to the available data and judgement by electrical analysis, the sedimentary layer 80-160 m thick

has three principal water-containing layers, the cross-section of the layer, the amount of water in each layer, and the water quality being unknown. The survey requires the use of bushings, accurate ground layer data and a filter diameter not less than 6"; it also requires the amount of water in each layer and the water quality to be known in hopes that it will be combined into a production well. But the team who is responsible for this survey has only 10" and 8" bushings. (According to past drilling methods), the survey team would not be able to do the job. However, the team did the job by adopting the combined method. Hole #108, which is the deepest in that sedimentary layer, is selected for illustration. The procedure of the survey is as follows:

First step: Put a 20" bushing 4-8 m long, as required (a wooden bushing can be used) in the hole as a conducting pipe for hole expansion by liquid mud (Fig. 1).

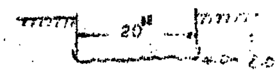

Fig. 1

Second step: In the conducting pipe, a 10" bushing is bored 40 m, and then an 8" bushing is continuously bored. The first water layer is discovered at 41 m; the bottom of the first water layer is found at 70 m; and boring is continued to 87 m and then stopped (Fig. 2). As specified in the hydrogeological survey, rock samples in the bushing should be collected to determine the water table, the static water level, the water temperature, etc.

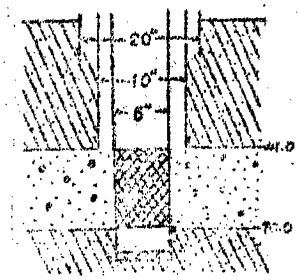

Fig. 2

Third step: A 6" filter is placed in the first water layer and the 8" bushing is taken out. The pumping-water test should be made as specified (Fig. 3).

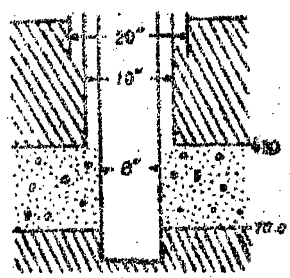

Fig. 3

Fourth step: After the pumping-water test, the filter is filled with concentrated mud with a viscosity of more than 40 sec. Then the 6" filter and the 10" bushing are taken out. The hole is widened by boring with liquid mud to a depth of 87 m (Fig. 4). Mud application standard exists when there

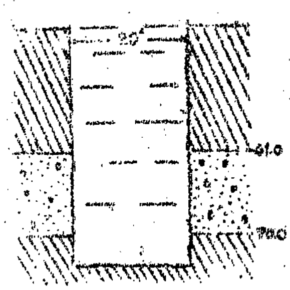

Fig. 4

is no gas and methane, and when the static water level of the underground water is 2 m above the hole opening. The sand and sandstone layer use mud with a viscosity of 18-22 sec and specific gravity of about 1.10; the clayey layer uses mud with a viscosity of 17 sec or pure water.

Fifth step: A 10" bushing is placed in the hole and struck down 0.5-1.0 m for mud separation. The mud in the bushing is pumped out and a 10" bushing is inserted to 2 m. Experience proves that when a bushing enters 0.5 m, the mud can be separated so that the drilled layer will not be dirtied by mud. Liquid mud should be supplied constantly to the 10" bushing to maintain the static pressure at a definite height (2m higher than the underground water). The liquid mud sediments in the hole slowly form plaster in the bottom, which will not affect the pulling of the bushing.

An 8" bushing follows the 10" bushing and is bored down to 90 m, where the second water layer is reached, and then to 125 m, where the bottom of the second water layer is found. Then, the boring is stopped (Fig. 5). Hydrogeological observations and sample collections are made accordingly at the section between 87-132 m in the bushing.

Sixth step: Same as the third step. Pumping-water test should be made in the second water layer (Fig. 6).

Seventh step: Same as step 4. Liquid mud is poured in. The filter and bushing are taken out. The hole is widened by drilling with mud to 132 m (Fig. 7).

Eighth step: Same as step 5. A 10" bushing is placed in the hole and an 8" bushing is bored to 135 m where the third water layer is reached and then to 165 m where rock-bed is reached (Fig. 8).

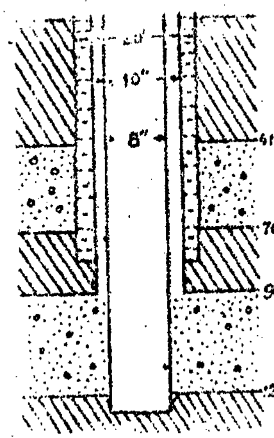

Fig. 5

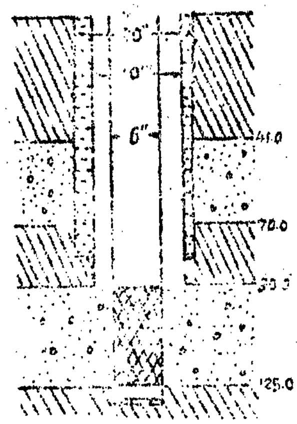

Fig. 6

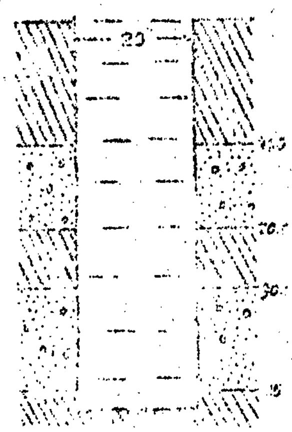
Fig. 7

Ninth step: Same as step 3. Pumping-water test should be made in the third water layer. (Fig. 9)

Tenth step: The hydrogeological conclusion is made for the boring hole. According to pumping-water tests, the overrun quantity of water layers 1, 2, and 3 exceeds 30 liters/sec in each layer. The water quality of the first and second water layers meet the requirements for drinking purposes, while the third water layer is not adequate for drinking.

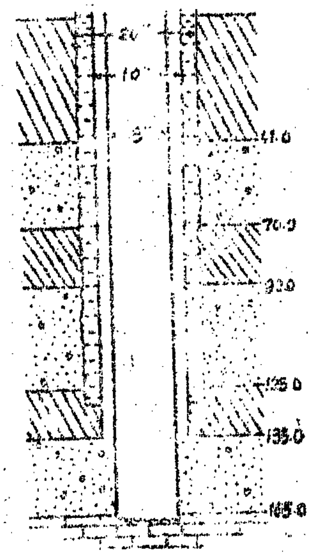

Fig. 8

Eleventh step: Same as step 4. The filter and bushing in the third water layer are taken out. From the above conclusion, the water quality is the third water layer is not adequate for drinking purposes. Therefore, it is not necessary to again widen the hole by liquid mud. Clay is used to seal the third water layer. A filter with a large diameter is installed in the first and second water layers only (Fig. 10). Finally, the well is washed and handed to the production organization for use.

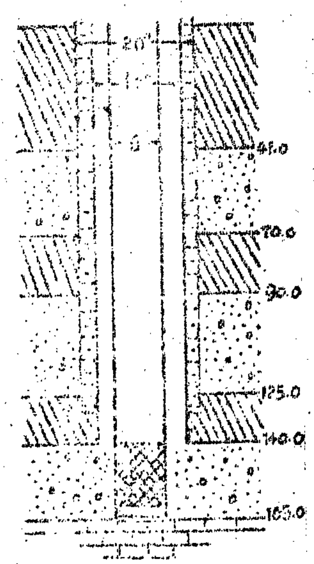

Fig. 9

Conclusion and Evaluation.

1. The combined method can save a considerable amount of bushings as compared with the bushing method. For instance, hole #108 needs more than 400 m of bushing with diameters of 8", 10", 12" and 24" by the bushing method; but it requires only 290 m of bushing with 8" and 10" by the combined method. Each hole can save 110 m of bushing weighing 10 tons, thus saving a large transportation cost. Moreover, the combined method can be performed without using bushings with diameters larger than 12" and 14", thus avoiding interruptions of work waiting for delivery of the bushings.

2. The widened hole by the combined method can be used as a production hole because it has a large diameter that will fit all types of filters, such as cast iron pipes and wooden pipes of large diameter. Since the hole diameter is widened, a gravel filling filter was invented to be adopted.

Thus, pumping-water tests can be carried out in fine sand and clayey sand water layers. The bushing method can not do this simply because of the diameter limitation. In addition, the combined method is simpler and more reliable in dividing the layers and sealing the water. It is easier to pull out the bushings (the bushings diameter is smaller than the hole's) and it is also suitable for deep holes of water layer (over 150 m).

3. The serious demerit of the combined method is that work progress is greatly reduced by widening the mud hole; during drilling, the boring machine can not develop its full working capacity. This limits the extensive use of this method. Therefore, it would be worthwhile to study this method further, in order to achieve a better, faster, and more economical method for hydrogeological investigation.

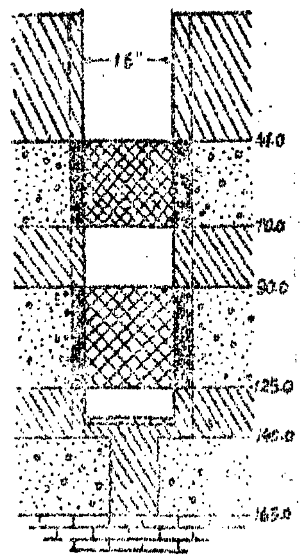

Fig. 10

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EXPERIENCES REGARDING WATER TABLE, WATER TEMPERATURE AND WATER QUALITY TESTS IN WATER LAYER DURING MUD DRILLING

/Following is the translation of an article by the Geological Bureau, Ho-pei Province, in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 25-26./

During the water supply reconnaissance survey at Kuang-hua salt field in August 1958, our team adopted the mud drilling method, with observations of the static water level, the water temperature and the water quality of each layer, with preliminary success.

Based on several deep hole data, the boundary line of the highly mineralized water in the K'uang-hua salt field was found around 200 meters deep. Therefore, we decided to use the individual layer observation method above 200 m to determine the vertical variation order of underground water mineralizability, the depth of the water supply and the method of isolating highly mineralized water in the upper part.

I. Test apparatus.

1. A 108 mm bushing.
2. A water bucket made of a sand collector.
3. Palm skin, sea-plants, wire and rope.
4. A thermometer, a water level measuring meter, and water sampling equipment.

II. Test procedure.

1. After mud drilling 1 m into the water layer, the drilling equipment is pulled up and sand samples are collected. If the water layer is composed of sand, the test can be started. The drilling equipment is pulled up and the 108 mm bushing which is wrapped with palm skin and sea-plant for water sealing at its bottom end is placed in the hole. The position of the water sealing is made on top of the water

layer where the ground layer is non-permeable. A stable ground layer within 10 m above the top of the water layer is selected, and a section is again wrapped with water sealing material (use #14 wire for wrapping). Then press the 108 mm bushing into the sand layer about 10 cm. The hole opening should be clamped.

2. The water sealing material should be wrapped about 50 cm long for each section; its outside diameter needs slightly less than the hole diameter (in agreement with the size of the drilling head); it should be tightened at the top, but let loose at the bottom in order to have close contact with the hole wall at the bottom of the hole.

3. The mud is removed from the bushing: First the drilling equipment is put 5-6 m above the bottom of the hole. After taking the mud out of its upper part, the drilling equipment is lowered to the bottom. Water is supplied for a few minutes to clean the mud in the sand layer. Then the depth of the hole is determined. If there is no sediment, a water bucket is used to pull the water up and the liquid mud outside the bushing is observed to see if it is lowering.

4. Bucketing should be slow at first and then gradually speeded. If the mud outside the bushing does not drop seriously after bucketing has started, the bucketing speed can be increased. When clean water can be recovered in the bushing while bucketing, and when the mud level outside the bushing does not show a lowering, the water sealing process is considered to be effective.

5. The hole depth should be determined after the water bucketed from the bushing is clean. Any sedimentation of sand or mud should be noted.

6. The static water level is observed after the water is clean; meanwhile, the water temperature is recorded and a water sample is taken for analysis. For this step the following conditions should be noted: (a) When sedimentation of sand and other material occurs in the hole bottom, a water sample should be collected, and a water temperature observation should be made, immediately after completion of bucketing in the bushing (more than twice the bushing volume). However, the water level can not be determined because it usually rises very slowly. (b) When no flowing sand and no sedimentation occurs in the bottom of the hole, water temperature observation, water level determination and water sample collection can be done immediately after completion of water bucketing in the bushing (more than twice the bushing volume). Observed also is the recovering water level until the curve reaches the inflection point.

7. Mud is poured into the bushing to replace the water after completion of the observations and sampling, and

then the bushing is pulled out. Drilling is continued to the second water layer and the procedure above is followed.

III. Test experiences.

First layer: Hole depth was 68.17-71.17 m. Fine sand. Tests were made four times.

1. First test: A 50 mm drilling rod with filter equipment attached at its lower end was placed in the sand layer. Water in the water layer did not rise because the filter could not be inserted deep enough into the water layer and because it was choked by mud. The test failed.

2. Second test: 108 mm bushings were used and a 0.5 m long, pointed filter (made of 6 steel rods welded in a cone shape with copper wire wrapped outside) was connected to the lower end of the bushing. A section of water sealing material was wrapped outside the bushing above the top of the water layer. Due to a miscalculation of the hole depth, the bushing could not be drilled in. Meanwhile, the filter equipment was broken. After water had been pumped out by a piston for over 10 minutes, mud began flowing into the bushing, and the mud level outside the bushing quickly lowered. This test also failed.

3. Third test: Again the bushing was equipped with a 0.5 m long pointed filter at its lower end; water sealing was done as in the previous test. The bushing was drilled into the sand layer. After water had been pumped up by a piston for over 10 minutes, mud still slew into the bushing, and this test was a failure.

4. Fourth test: Based on the condition of mud flowing into the bushing, the water sealing method was improved by adjusting the sealing position closer to the top of the water layer. A stable section of the ground layer within 10 m above the top of the water layer was selected for water sealing. The bushing was placed inside as usual, but a bucket was used for pulling up the water. The result was good. Water could flow into the bushing from the water layer without mud flow. This test took about 5 min to pull out 20 liters of water; the water level dropped to 10 m below the ground surface; the recovery water level was 3.3 m, lowering about 7 m. The result of water sample analysis indicated that the water contained solids of 11855 mg/l, K+Na 3383.99mg/l, and Cl 5388.65 mg/l. It was very salty, being quite different from the quality in the upper part of the ground layer.

5. The first water layer had four tests. The time for the first test was not recorded. Five shifts (including putting in the bushing) were required for the second, third and fourth tests.

Second water layer: Hole depth was 135.44-139.16 meters, fine sand. The test was performed only once. Two sections of water sealing were made at the top of the water layer and above the water layer. After the bushing was placed down, the mud in the bushing was taken out. Water was removed by a bucket; over 60 m of flowing sand occurred at the bottom of the hole. Therefore, in order to save time, only a water sample collection and a water temperature observation were done without observing the water level.

Third water layer: Hole depth was 193.72-196.20 meters, fine sand. Two tests were made. The first test was not a success due to the fact that the wrapping of water sealing was broken by the friction of the bushing. The second test was similar to the procedure followed in the second water layer. Flowing sand was found in the bottom of the hole; water rose too slowly. Due to a lack of long, steel rope, removal of the water from the bushing had to be stopped. Only a water sample collection and a water temperature observation could be done. Nine shifts were assigned to pull out the water because of the slow rising of the water level. Therefore, because mud was settling around the bushing, the bushing was accidently buried.

IV. Cautions

1. For testing purposes, the hole depth should not be too deep; a depth between 100-150 m is recommended. A stable area should be selected because a deep hole has many sediments, making it difficult for the bushing to be pulled out and limiting the diameter of the hole.

2. Drilling the hole's diameter: A 7" hole diameter should be made if a 108 mm bushing is adopted for testing. If the bushing is buried, a drilling rod can be applied outside the bushing to save it from being buried.

3. The diameter of the water sealing wrapping should agree with the size of the hole; the sealing position should be a stable ground layer. Two sections of sealing are necessary.

4. Sealing should be properly done to prevent leakage and to avoid sliding of the hole. The water sealing process is actually the most important factor to the effectiveness of the test.

5. Good quality mud should be used before the bushing is put in the hole. Its viscosity should be high in order to protect the hole wall.

6. The time for testing should not be too long. Otherwise, the bushing will be easily buried by sedimented mud.

7. Equipment and material should be ready for use, especially steel ropes and other emergency tools. Less time

will be required if steel rope is used for pulling the bucket, besides being safer.

8. Since the upper part is a brine district, it is better to use non-salty water for mud washing. The liquid in the bushing should be ta en out to examine the quality of the water.

V. Conclusion

1. The tests proved that a hydrogeological survey can be made on a mud hole. If bushings are lacking and speedy drilling is needed, the mud drilling method can fundamentally collect the same required data as water drilling.

2. The ground layer of the tests is fine sand; the depth of the holes is more than 200 m. After a preliminary study, it was decided that this method is applicable to self-flowing water districts. The time for washing and bucketing can be reduced by using self-flowing water, but the sand flowing problem at the hole's bottom in water-bearing districts still must be solved. Whether other layers, such as sand-gravel, are applicable is pending further test proof.

3. Only one set of 108 mm bushings was added to the tests; each test requires about 2 shifts. Each observation of an individual water layer requires wasting some mud in the bushing and having more clay consumed. However, the data obtained is far more accurate than that from a mud hole.

4. The piston type equipment to remove water has a great enough force to suck the mud from around the bushing; the bucket seems better, but the efficiency is lower. The water sealing process should be improved so that the more effective piston type equipment can be adopted.

5. Moreover, it takes so much time for each observation that the bushing might be buried. This should be studied further for improvement.

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PROBLEMS OF THE REMAINING WATER IN THE BORE HOLE IN PRESSURE-WATER EXPERIMENTS

[Following is the translation of an article by Li Ch'eng-ts'ai (2621 2052 6299), in Shui-wen Ti-chih Kung-ch'en Ti-chih, No. 11, 12 November 1959, pp. 27-28.]

Most test sections of a dry boring hole at a dam shoulder are above the underground water level. Liquid washing and pressure-water experiments are applied along with the drilling, so that the dry rock layer absorbs the water and temporarily reaches a saturated condition. Then the remaining water appears in the hole. In a definite period the remaining water becomes constant so that water flows back into the hole, balancing with the water that permeates into the rock layer. This balancing condition forms a stable false underground water level, which can be kept for several days in a rock layer of low permeability. In the past, it took more than a week for the remaining water to be permeated. This waiting period could not meet our fast, economical principles. The author, having several years experience in pressure-water tests, presents a few points telling how to treat the remaining water in the bore hole.

Section I

If the height of the water level is designed by a dry hole in a pressure-water experiment, without considering the affect of the remaining water in the bore hole, it is very possible to produce the following two conditions:

1. A false water level stable condition: Since we do not recognize a stable false water level because of the dry hole, during a pressure-water test the rising height of the water level is one-half of the test length plus S (Fig. 1). Then the total height of the water head is:

$$\frac{1}{2} l + S \qquad (1)$$

l = the test length in m.

Actually, the stable false water level is h meters from the bottom of the test section. Therefore, the actual raise in height of the water head should be

$$\tfrac{1}{2}(1 - h) + S \qquad (2)$$

From (1) and (2) we get:

$$\tfrac{1}{2}\,1 + S - \tfrac{1}{2}1 + \tfrac{1}{2}h - S = \tfrac{1}{2}h \qquad (3)$$

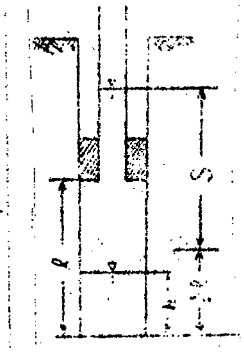

Fig. 1

Thus, the rising height of the water level that we designed will be $\tfrac{1}{2}h$ less than the actual condition.

When the water flow becomes a layer flow, the flow rate is proportional to the water head, following "Ta-erh-hsi"'s law. The unit water absorbing quantity is constant regardless of the height of the water head:

$$q = \frac{Q_0}{H} \qquad (4)$$

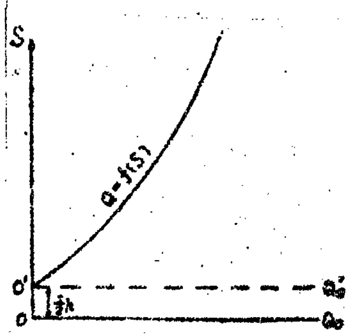

Fig. 2

When the water flow becomes divergent, the area around the hole produces a condition that does not agree with "Ta-erh-hsi"'s law. The relationship between the water head and the flow rate can be expressed by the following equation:

$$H = aQ_0\ bQ_0^2 \qquad (5)$$

or:

$$Q_0 = n\sqrt[m]{H} \qquad (6)$$

It is evident from equations (4) and (6) that the unit water absorbing quantity is a constant; when the rising height of water level drops $\tfrac{1}{2}h$, the pressure-water flow rate Q decreases accordingly. This is reflected on the curve $Q = f(S)$, which does not pass through the point of origin (Fig. 2).

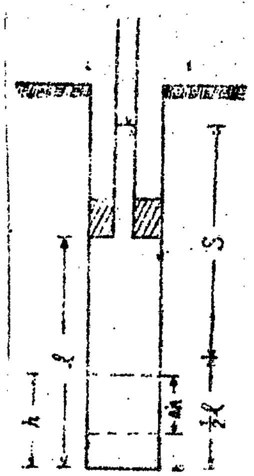

Fig. 3

2. A false water level unstable condition: Since the false water level changes from time to time, let's assume that the false water level drops Δh at time Δt (Fig. 3). Then the actual rising of the water level increases Δh. Similarly, from (4) and (6), we know that when the rising height of the water level increases from $\tfrac{1}{2}(1-h)+S$ to $\tfrac{1}{2}(1-h-\Delta h)+S$ the pressure-water flow rate increases also.

When the remaining water in the hole lowers and the rising height of the water level increases, the pressure-water flow rate Q should increase accordingly. The stable condition $Q = f(T)$ is: $\frac{Q_{max} - Q_{min}}{Q_{min}} \leq 10\%$

When the stable condition cannot be satisfied, the reaction of the water level and the flow rate on the curve becomes unstable, too, (Fig. 4) and the experiment cannot be successful. Therefore, the remaining water in the hole should be considered in a pressure-water experiment.

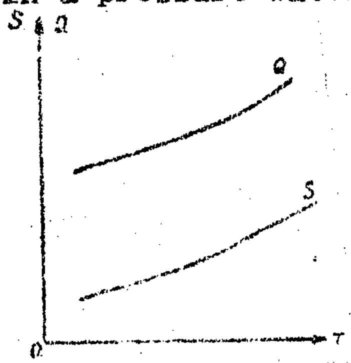

Fig. 4

Section II

After working for several years, we gradually found some guides to the remaining water in the bore hole and a method to solve this problem. Our practical experiments proved that this method does not affect the results qualitatively or quantitatively.

1. The stable false water level in the bore hole is low when the depth of the hole is deep.

2. Since the permeability of each section of the rock layer in the hole is different, the stable false water level of the remaining water is variable, too. In order to get a water level height as the basis for design, it is necessary to determine the stable false water level before any pressure-water experiment is made.

3. The observed water level in the hole cannot be used as a design basis for the rising height of the water head before it is properly corked. After it is corked, the permeating water from the upper part of the test section is stopped, breaking the existing stable condition and creating a new stable false water level. Therefore, it is necessary to properly cork without any leakage and then to determine the stable false underground water level in the hole. The result of this is the rising height of the water head for the basis of design.

4. In order to shorten the time of determining the stable false water level, do not wait for its stable before

corking. It is necessary to pump out a part of the remaining water (the amount to be pumped out should agree with its permeability) and then tightly cork it. After checking that there is no leakage, the water level in the hole can be determined. If the false water level is decreasing, it illustrates that the stable false water level is still below the existing water level. Under such a condition, pumping pipe with a 4 mm diameter and 2-4 m long is used to pump the water out of the inner pipe. This helps to lower the water level and to quicken the stablization of the water level. If the false water level is increasing, it illustrates that the stable false water level is still above the existing water level. Under such a condition, a suitable amount of water is added to the inner pipe to help its recovery.

5. In the determination of the false water level, the variation should not exceed 2-3 cm in one hour.

6. If the stable false water level is within the test section, it is still measured from the test section which is the design basis for the rising height of the water level. If the stable false water level is higher than the test section, it should be measured from the stable false water level which is considered to be the zero point for designing the rising height of the water level.

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